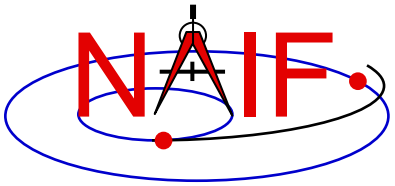

Navigation and Ancillary Information Facility

Planetary Constants Kernel
PCK

October 2022

Topics

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- Binary PCK Orientation Models
- PCK reference frames
- PCK Shape Models
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Overview

- **The Planetary Constants Kernel (PCK) subsystem comprises both text and binary kernels.**
  - **Text PCKs provide orientation and shape models for the sun, planets, natural satellites and a few asteroids and comets.**
  - **Binary PCKs are used only when very high accuracy orientation data are available.**
    - » **Currently available only for the earth and the moon**
    - » **One still needs to use a text-style PCK to get shape data**

Text PCKs - 1

- **Text PCK files contain size, shape and orientation data associated with natural solar system bodies: planets, satellites, and a few comets and asteroids.**
  - **Some additional kinds of data might also be included.**
- **NAIF creates and distributes a "generic" text PCK based on the latest IAU/IAG Report.***
  - **The reports are issued about once every three years, and so might not contain the very latest available results.**
- **SPICE PCK software is designed to use these data to compute orientation of body-fixed, body-centered frames.**
  - **These frames have a name style of "IAU_*body-name*"**
- **NAIF also provides a "masses" PCK, containing GM values for the Sun and planetary systems.**
  - **Values from this file are typically used with SPICE osculating element routines, and in using the MKSPK application to make a Type 5 SPK file.**
- **Text PCKs are sometimes produced by flight projects and others–not only by NAIF.**

* "Report of the IAU/IAG Working Group on cartographic coordinates and rotational elements: <year issued>"; published in *Celestial Mechanics and Dynamical Astronomy*

Text PCKs - 2

- **The SPICE text kernel mechanism is used to implement PCK files.**
  - **Kernel variables contain the mathematical terms appearing in rotation or shape models. For example:**

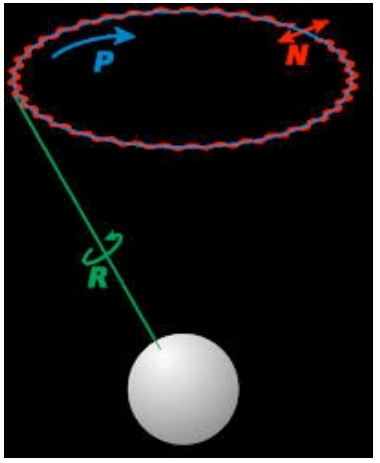
```
BODY699_POLE_RA =   ( 40.589   -0.036      0. )
BODY699_POLE_DEC =  ( 83.537   -0.004      0. )
BODY699_PM =        ( 38.90   810.7939024  0. )
BODY699_RADII   =   ( 60268    60268   54364   )
```

  - **Users may easily inspect data in text PCKs.**
  - **Users may (carefully!) modify text PCKs with a text editor.**
    - » **Data or comments may be added, deleted, or changed.**
    - » **Comments should be added to explain changes.**
  - **The user may include additional kernel variables to change the base frame or reference epoch.**
  - **Kernel variable names are case-sensitive.**
    - » **NAIF uses only upper case for variable names; we suggest you do the same.**

Text PCK Orientation Models - 1

- **For the sun, planets and a few major asteroids:**
  - **PCK models use low-degree (typically linear) polynomials to represent RA and DEC of the pole (body-fixed +Z-axis) as a function of time.**
  - **The prime meridian is also represented by a low-degree polynomial.**
  - **For a few planets, trigonometric polynomial terms are used to more accurately represent precession and nutation of the pole.**

R = rotation of the body about its rotational axis
P = precession of the bodies' rotational axis
N = nutation of the bodies' rotational axis



- **For natural satellites:**
  - **In addition to low-degree polynomials for the spin axis and prime meridian, trigonometric polynomial terms are used to more accurately represent precession and nutation.**
  - **A few satellites have chaotic rotation and so are not modeled.**

Text PCK Orientation Models - 2

- **The base frame for PCK orientation models is the International Celestial Reference Frame (ICRF), as defined by the International Earth Rotation Service (IERS).**
  - **For historical and backwards compatibility reasons, SPICE uses the name "J2000" as a synonym for the ICRF inertial reference frame, even though J2000 and ICRF are, in fact, not identical. (The difference is well under 0.1 arc second.)**

Text PCK Orientation Models - 3

- **Body-fixed frames provided in text PCKs have +Z axes consistent with planetocentric coordinate systems. The +X axes of these frames coincide with planetocentric longitude 0.**

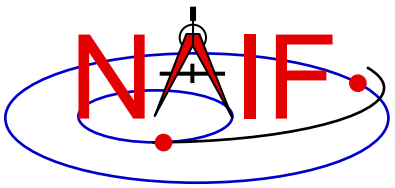
- **For planets and satellites the +Z axis (+90 LAT) always points to the north side of the invariable plane – the plane whose normal vector is the angular momentum vector of the solar system.**
  - **Planetocentric longitude increases positively eastward**
  - **Planetocentric latitude increases positively northward**

- **Dwarf planets*, asteroids and comets spin in the right hand sense about their "positive pole."**
  - **What the IAU now calls the "positive pole" is still referred to as the "north pole" in SPICE documentation.**
  - **The "positive pole" may point above or below the invariable plane of the solar system (see above).**
  - **This revision by the IAU Working Group (2006) inverts what had been the direction of the north pole for Pluto, Charon and Ida.**

*The dwarf planets are: Ceres, Pluto, Haumea, Makemake, Eris

Binary PCK Orientation Models

- When available, the SPICE system can store high-accuracy orientation model data in binary PCKs.
- Binary PCKs are limited to storing orientation data.
  - Applications that require shape data must also load a text PCK.
- Orientation data from a binary PCK always supersede orientation data for the same object obtained from a text PCK, no matter the order in which the kernels are loaded.
- Binary PCKs for the earth and the moon are available from the NAIF server.
  - The accuracy of these is much better than what is provided in the generic text PCK.
  - See the tutorial "lunar-earth_pck-fk" for details.



Location of Text PCK Reference Frame Specifications

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- **Many PCK reference frame specifications are built into SPICE. Examples are IAU_SATURN and IAU_TITAN.**
  - **To use these, load a text PCK file containing orientation data for the body of interest.**
    - » **Typically this is the current generic text PCK**
  - **Be very cautious about using IAU_EARTH and IAU_MOON; the binary PCKs for these two bodies offer much more accuracy.**
  - **Data for a small number of comets and asteroids are included.**

- **Other PCK frames are not built-in and must be defined in a frames kernel that is loaded by your program. Examples are body fixed frames for asteroids or "newer" natural satellites.**
  - **See the Frames Required Reading technical reference for information on creating frame kernels that specify PCK reference frames.**

Location of Binary PCK Reference Frame Specifications

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- **Special high-accuracy earth and lunar body-fixed frames are realized using binary PCKs.**
  - **These frames are named:**
    - » **For the earth: ITRF93**
    - » **For the moon: MOON_PA and MOON_ME**

- **To use high-accuracy earth or moon orientation, load the appropriate binary PCK and allied FK.**
  - **See the special tutorial "lunar-earth_pck-fk" for details on these.**

PCK Shape Models

- PCK shape models are nominally triaxial ellipsoids
  - For many bodies, the two equatorial axes have the same value; these bodies have a spheroidal shape.
  - For some bodies, one or more radii have not been determined.
  - See the DSK tutorial for information about other kinds of shape models available within SPICE.

- Although many bodies are in fact modeled as spheres or spheroids, SPICE usually deals with the general, triaxial case.
  - Exception: SPICE supports geodetic coordinate transformations only for bodies modeled as spheres or spheroids.
    - » RECGEO, GEOREC, DGEODR, DRDGEO and XFMSTA are the modules performing these transformations.
  - Exception: SPICE supports planetographic coordinate transformations only for bodies modeled as spheres or spheroids.
    - » PGRREC, RECPGR, DPGRDR, DRDPGR and XFMSTA are the modules supporting these transformations.

Using PCK Data

- **PCK orientation data are usually accessed using frame subsystem or ephemeris subsystem APIs.**
  - **Example: Get the IAU_SATURN body-fixed reference frame to J2000 position or state transformation matrix at ET:**
    - **CALL PXFORM ('IAU_SATURN', 'J2000', ET, RMAT)**
    - **CALL SXFORM ('IAU_SATURN', 'J2000', ET, XFORM)**

Fortran examples

  - **Example: Get the state of Saturn relative to Cassini in the IAU_SATURN body-fixed reference frame:**
    - **CALL SPKEZR ('SATURN', ET, 'IAU_SATURN', 'LT+S', 'CASSINI', STATE, LT)**

- **PCK shape data are usually accessed using APIs needing size and shape data such as SUBPT, SUBSLR, ILUMIN, etc.**

Interface Routines - 1

- **Call FURNSH to load PCKs.**
  - **CALL UNLOAD or KCLEAR to unload them.**
- **Call SXFORM to return a state transformation.**
  - **Returns 6x6 matrix (attitude and angular velocity)**
    - » `CALL SXFORM ( FROM, TO, ET, XFORM )`
- **Call PXFORM to return a position transformation.**
  - **Returns 3x3 matrix (attitude only)**
    - » `CALL PXFORM ( FROM, TO, ET, RMAT )`

Fortran examples

- **Get state of Saturn relative to Cassini in the IAU_SATURN body-fixed reference frame:**
  - `CALL SPKEZR ( 'SATURN', ET, 'IAU_SATURN', 'LT+S', 'CASSINI', STATE, LT )`
- **Get state of Cassini relative to the DSN station DSS-13 in the J2000 inertial reference frame:**
  - `CALL SPKEZR ( 'CASSINI', ET, 'J2000', 'LT+S', 'DSS-13', STATE, LT )`
    - » **An Earth PCK must be loaded in order for this call to work, even though the requested output reference frame is inertial.**
      - **That's because, in the course of its work, this call must convert the position of the DSN station relative to the Earth's center from an Earth-fixed, earth-centered frame to the J2000 frame.**

Interface Routines - 2

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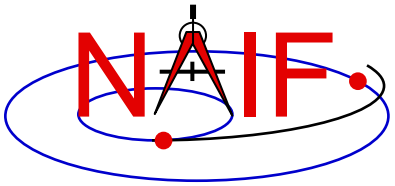
Fortran examples

- **Call BODVRD or BODVCD to retrieve constants associated with a body. For example:**
  - `CALL BODVRD ( 'SATURN', 'RADII', 3, N, RADII )`
  - `CALL BODVCD ( 699, 'RADII', 3, N, RADII )`

  - These calls retrieve values associated with the variable BODY699_RADII.
  - The variable name is case-sensitive, so the string, RADII, above must be in upper case.

- **You can use general kernel pool fetch routines to fetch data assigned to any non-standard names.**
  - GCPOOL, for character data
  - GDPOOL, for double precision data
  - GIPOOL, for integer data



PCK Precedence Rules

- **In text PCKs, assignments are of two types:**
  - » **"Direct": variable name = value(s)**
  - » **"Incremental": variable name += value(s)**
  - – **The last direct assignment made to a given variable replaces any/all previous assignments for that variable.**
  - – **Incremental assignments simply add additional values to an existing variable.**
    - » **The variable will be newly created if it didn't already exist.**

- **Orientation data from a binary PCK always supersede orientation data (for the same object) obtained from a text PCK, no matter the order in which the kernels have been loaded.**

PCK Utility Programs

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- **These utilities are included in the Toolkit.**

BRIEF	summarizes coverage for one or more binary PCK files
SPACIT	generates segment-by-segment summary of a binary PCK file
COMMNT	reads, appends, or deletes comments in a binary PCK file
FRMDIFF	samples a PCK-based frame or compares orientation of two PCK-based frames (binary or text PCKs)

- **These additional utilities are provided on the NAIF Web site (http://naif.jpl.nasa.gov/naif/utilities.html).**

BFF	displays binary file format of a binary PCK file
BINGO	converts binary PCK files between big-endian and little-endian formats

Additional Information on PCK

- **For more information about PCKs, look at the following:**
  - **Most Useful Routines document**
  - **PCK Required Reading document**
  - **Headers of the routines mentioned**
  - **Lunar/Earth High-Precision PCK/FK tutorial**
  - **BRIEF and FRMDIFF User's Guides**

- **Related documents:**
  - **Frames Required Reading**
  - **Kernel Required Reading**
  - **NAIF_IDS Required Reading**
  - **Time Required Reading**